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(54) **METHOD OF FORMING A MAGNETIC DEVICE HAVING A CONDUCTIVE CLIP**

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H01F 27/30 (2006.01)

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USPC .... **29/602.1**; 29/606; 29/827; 252/62.51 R

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USPC .... 29/602.1, 604, 606, 827; 336/83, 200, 336/208, 82; 252/62.15 R, 62.6
See application file for complete search history.

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(57) **ABSTRACT**

A method of forming a magnetic device by providing a conductive substrate and placing a magnetic core proximate the conductive substrate with a surface thereof facing the conductive substrate. The method also includes placing a conductive clip proximate a surface of the magnetic core and electrically coupling ends of the conductive clip to the conductive substrate to cooperatively form a winding therewith about the magnetic core.

21 Claims, 3 Drawing Sheets

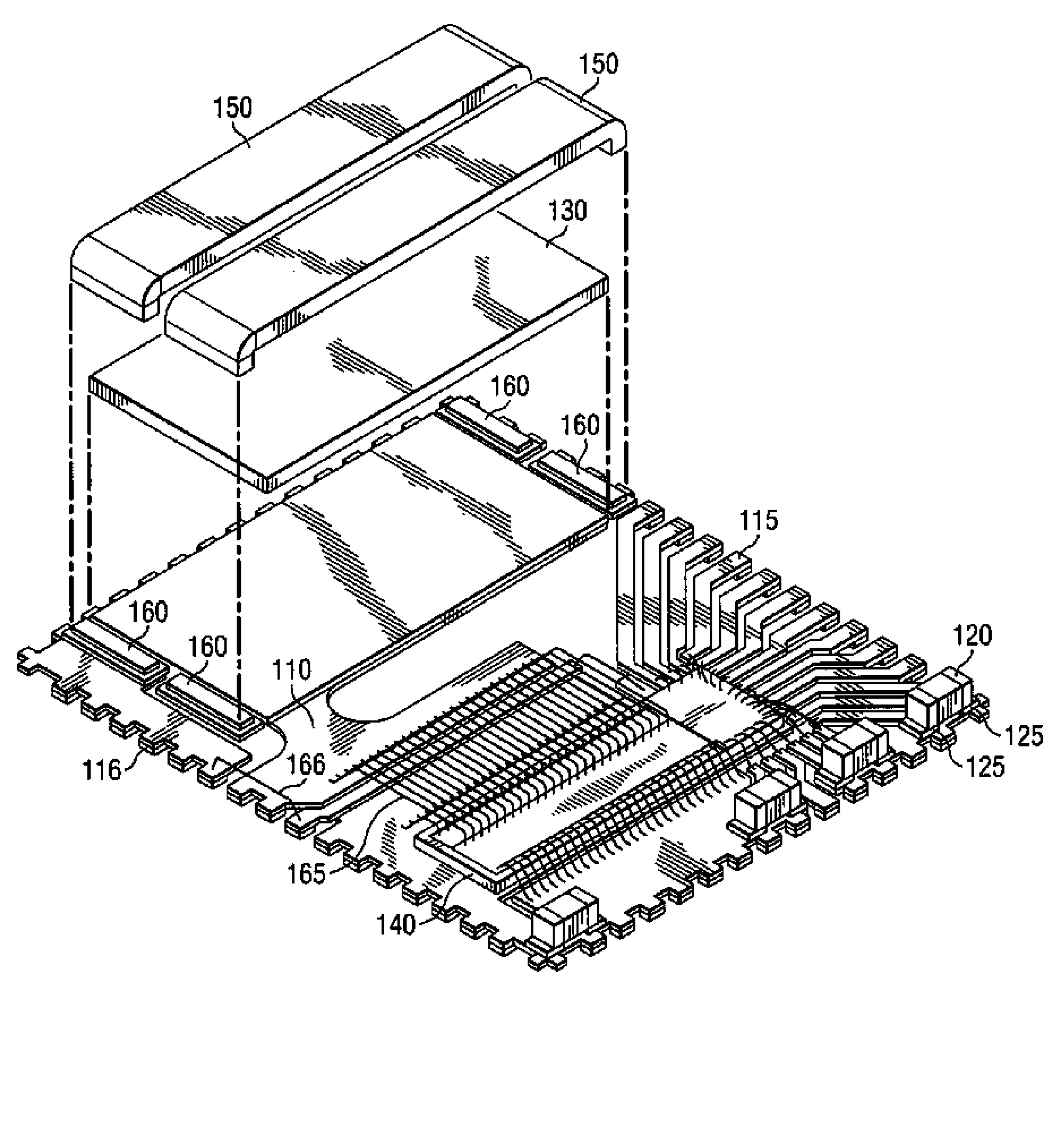

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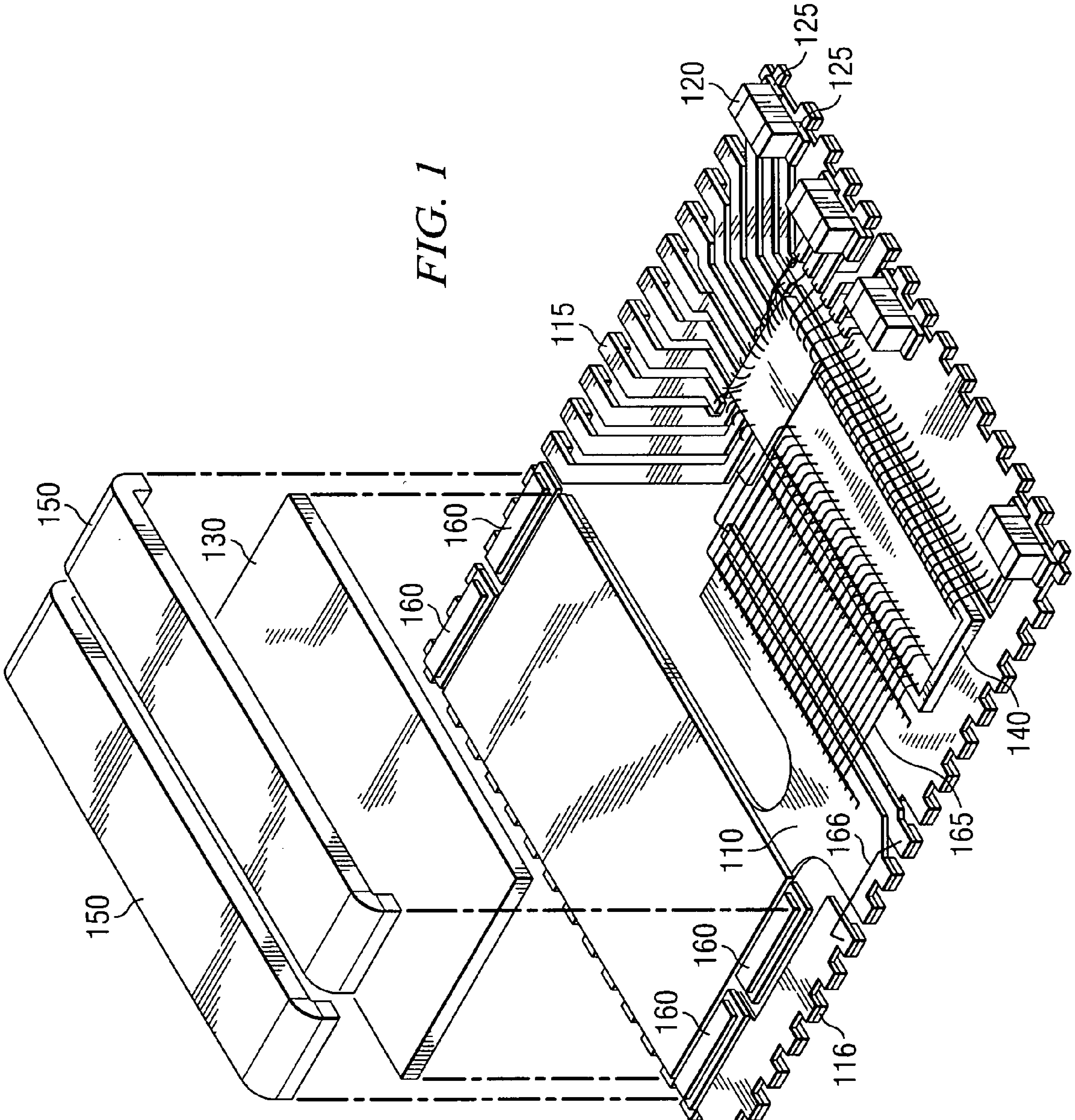
FIG. 1



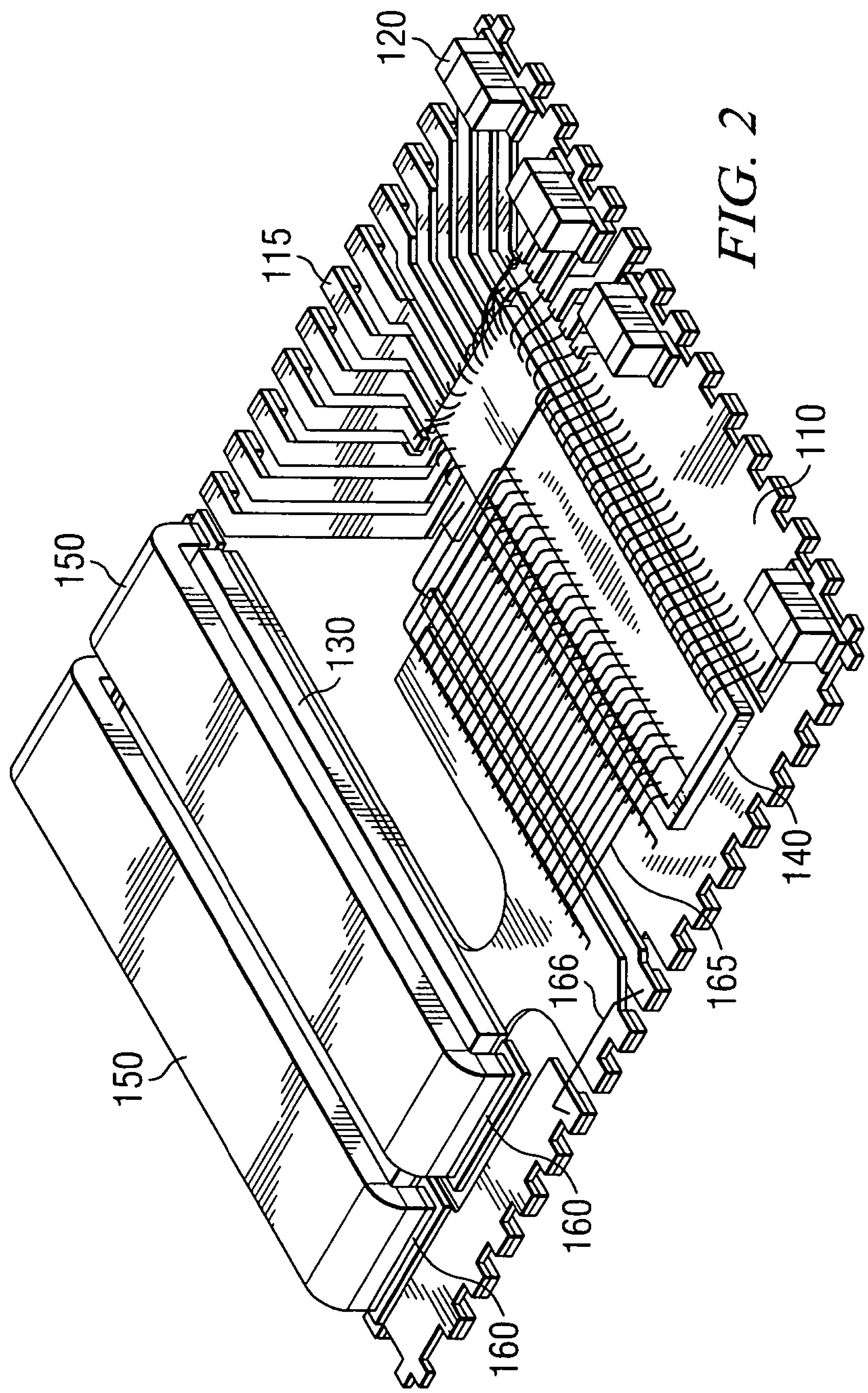
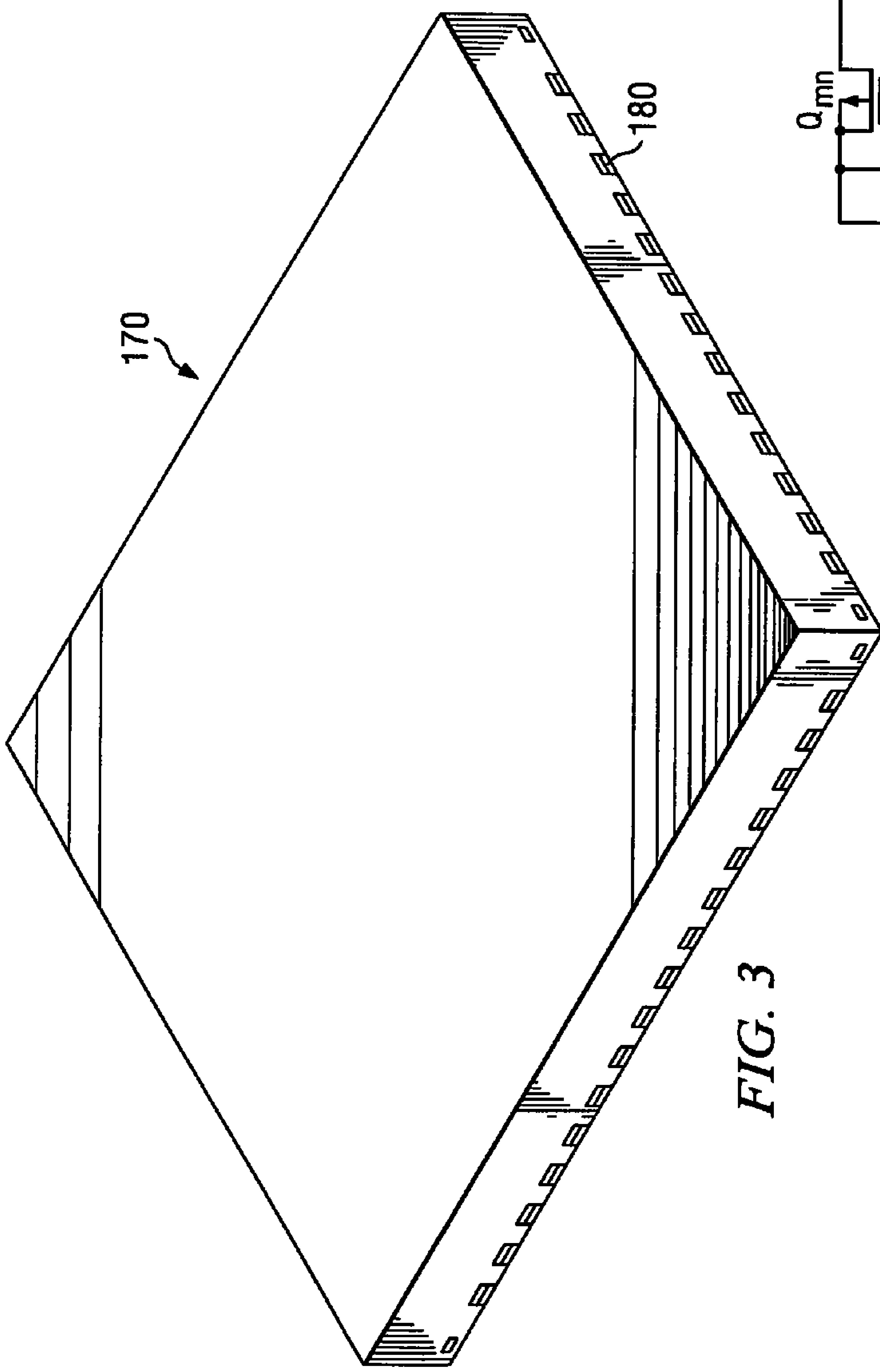


FIG. 2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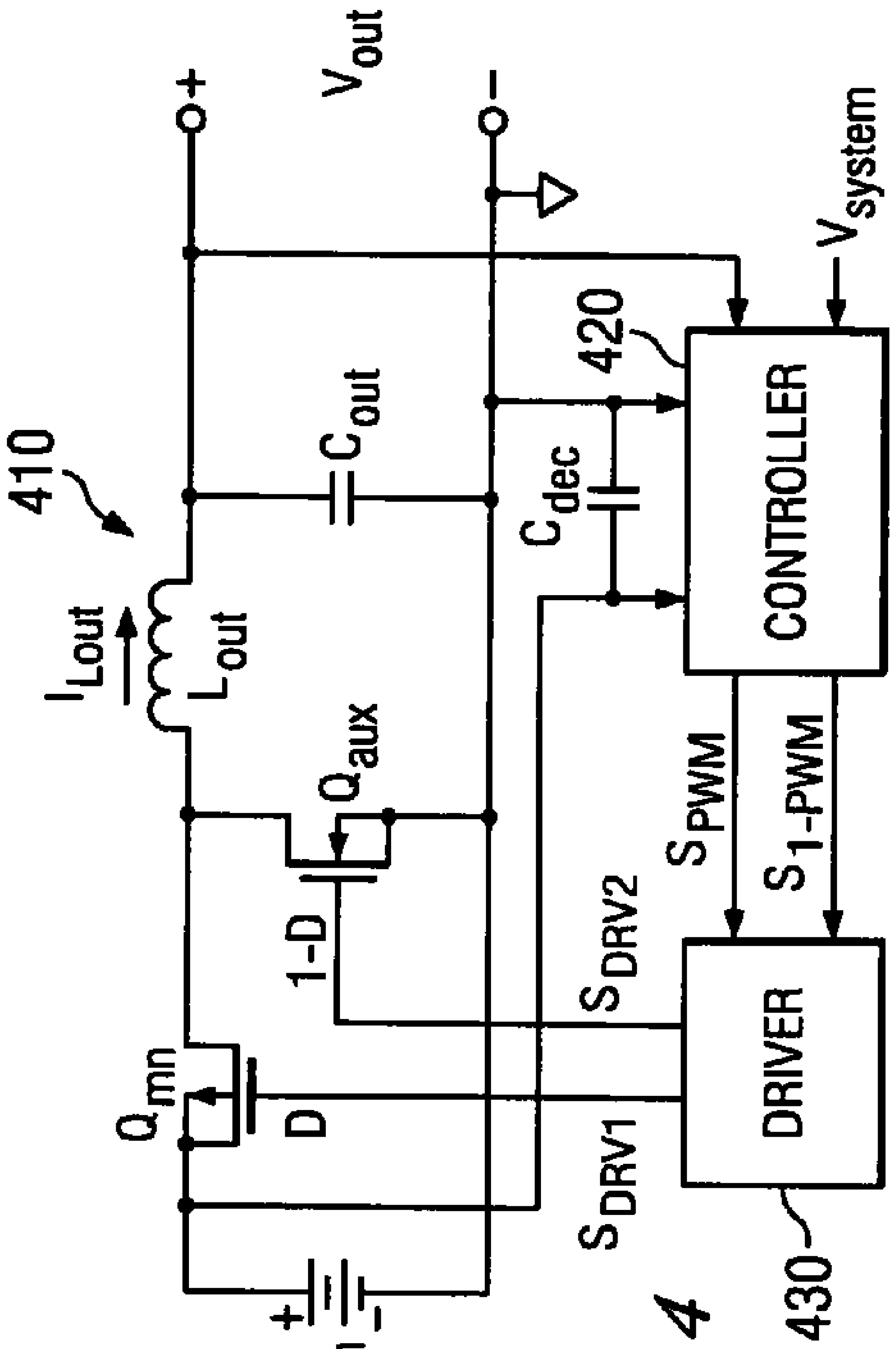
180

FIG. 3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Vout
−
Vsystem
420
CONTROLLER
Cout
Cdec
410
ILout
Lout
Qaux
SPWM
S1-PWM
1-D
SDRV2
DRIVER
Qmn
D
SDRV1
430
Vin

FIG. 4

METHOD OF FORMING A MAGNETIC DEVICE HAVING A CONDUCTIVE CLIP

TECHNICAL FIELD

The present invention is directed, in general, to electronic devices and, in particular, to magnetic devices and power modules, and related methods of forming the same.

BACKGROUND

Magnetic devices such as inductors are often used in circuit design for electronic devices (e.g., power modules) in which energy is stored in a magnetic field surrounding an electrically conductive element such as a coil of copper wire. To produce an inductor that can store a useful amount of energy for a given size and a given current level, a number of electrically conductive turns or wires are formed around a magnetic structure or core such as a layer of magnetic material. The magnetic field is enhanced by the permeability of the magnetic material and by the presence of the multiple conductive turns. As the size of electronic devices has been reduced by using integrated circuits and printed wiring boards with surface mount assembly techniques, the size of inductors has not, to date, decreased proportionately.

Attempts to use finer wire sizes have resulted in inductor designs with limited current handling capability. Silver is recognized as a slightly better conductor than copper for higher current levels, but its expense is generally not warranted in practical products. These effects have combined to make the design of magnetic devices a continuing object for further size and cost reductions without compromising the respective current ratings.

A number of approaches beyond the use of finer copper wire have been used in the past to produce smaller inductors. For instance, U.S. Pat. No. 6,094,123 entitled "Low Profile Surface Mount Chip Inductor," to Apurba Roy, issued Jul. 25, 2000 and U.S. Pat. No. 5,802,702 entitled "Method of Making a Device including a Metallized Magnetic Substrate," to Fleming, et al., issued Sep. 8, 1998, which are incorporated herein by reference, disclose magnetic devices that form recesses in a bar of magnetic material for conductors and deposit conductive material in the recesses. Additionally, U.S. Pat. No. 5,574,420 entitled "Low Profile Surface Mounted Magnetic Devices and Components Therefor," to Roy, et al., issued Nov. 12, 1996, which is incorporated by reference, discloses a magnetic device that forms conductive pathways in a body of magnetic material, adds windings by inserting staple-like conductive piece parts through apertures in the body, and solders the staples to a patterned printed wiring board placed below a ceramic magnetic bar to complete the winding structure. Each of the magnetic devices disclosed in the aforementioned references suffer from a current limitation therefor, which is an impractical design and manufacturing approach for a mass market. The aforementioned magnetic devices also provide inadequate heat dissipation capability or reduction in the size thereof.

Thus, the designs for the magnetic devices in the past are inadequate to produce a sufficiently miniaturized magnetic device with a substantial current rating for application in compact devices such as high density power converters embodied in power modules. The power converters often employ magnetic devices that can sustain currents exceeding one ampere and are operable at switching frequencies that exceed one megahertz. Additionally, the magnetic devices should exhibit very low electrical resistance at the switching frequency and should be more compact than presently achievable designs. The design of power converters is inadequately served by these aforementioned limitations of present magnetic devices. In addition, a magnetic device integrable with manufacturing processes of the commensurate end product such as a power module would provide substantial cost savings therefor.

Accordingly, what is needed in the art is a magnetic device, and related method of forming the same, that can meet the more stringent requirements of present applications such as compact, efficient and high density power modules, while being manufacturable at high volume and with lower cost than is achieved with the prior art.

SUMMARY OF THE INVENTION

These and other problems are generally solved or circumvented, and technical advantages are generally achieved, by advantageous embodiments of the present invention which includes a method of forming a magnetic device by providing a conductive substrate and placing a magnetic core proximate the conductive substrate with a surface thereof facing the conductive substrate. The method also includes placing a conductive clip proximate a surface of the magnetic core and electrically coupling ends of the conductive clip to the conductive substrate to cooperatively form a winding therewith about the magnetic core.

In another aspect, the present invention provides a method of forming a magnetic device by providing a patterned, conductive leadframe and adhering a magnetic core formed from a bar of magnetic material to the conductive leadframe. The method also includes placing at least one conductive clip above the magnetic core and soldering ends of the at least one conductive clip to the conductive leadframe to cooperatively form a winding therewith about the magnetic core.

The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGS. **1** and **2** illustrate isometric views of an embodiment of an electronic device, before encapsulation, constructed according to the principles of the present invention;

FIG. **3** illustrates an isometric view of an embodiment of an electronic device, after encapsulation, constructed according to the principles of the present invention; and

FIG. **4** illustrates a diagram of an embodiment of a power converter including power conversion circuitry constructed according to the principles of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The making and using of the presently preferred embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways to make and use the invention, and do not limit the scope of the invention.

The present invention will be described with respect to preferred embodiments in a specific context, namely, a magnetic device, an electronic device (e.g., a power module) and a method of manufacture thereof. As the size of magnetic devices continues to shrink, the magnetic devices are also referred to as micromagnetic devices. For the purposes of the present invention, the terms may be used synonymously. While the principles of the present invention will be described in the environment of a power module, any application that may benefit from a magnetic device as described herein is well within the broad scope of the present invention.

As will become more apparent, a magnetic device embodied in an inductor is formed with a magnetic core (e.g., a bar of magnetic material) proximate (e.g., above) a conductive substrate (e.g., an electrically conductive leadframe), and a conductive clip positioned proximate (e.g., above) the magnetic core to complete a winding thereabout (e.g., around). Thus, a surface (e.g., a lower surface) of the magnetic core faces (e.g., generally oriented toward) the conductive substrate and a surface (e.g., an upper surface) of the magnetic core faces (e.g., generally oriented toward) the conductive clip. As described herein, the magnetic core is formed of a medium that generally conducts a given magnetic flux level for a lower level of applied magneto-motive force, such as measured in ampere-turns, compared to a non-magnetic medium such as air (or a vacuum). The magnetic core may occupy a closed flux path such as provided by a torroidal structure, or may occupy a portion of a flux path such as provided by a flat or round bar of magnetic material. The magnetic core includes structures such as bars and rods, as well as films, and may include multiple layers including intervening layers and layers that improve the magnetic properties thereof.

In addition to the magnetic device, an electronic device such as a power module includes other integrated circuits (either in bare die or module form) and surface-mount components coupled (e.g., adhesively mounted) to the conductive substrate and electrically coupled thereto with wire bonds. An encapsulant such as plastic molded material is placed around the magnetic device, integrated circuit and/or the surface-mount components. The power module may also include a power conversion circuitry that includes or may be embodied in the magnetic device, the integrated circuit, and at least one surface-mount component. It should be understood that the power module may form, at least in part, a power management system, which itself is often referred to as a power management integrated circuit.

Referring initially to FIGS. **1** and **2**, illustrated are isometric views of an embodiment of an electronic device (e.g., power module), before encapsulation, constructed according to the principles of the present invention. The power module includes a magnetic device (e.g., inductor), an integrated circuit and surface-mount components. The power module may include power conversion circuitry that includes or may be embodied in the magnetic device, the integrated circuit and at least one of the surface-mount components. The power conversion circuitry may form a power converter that often includes switching regulators such as buck switching regulators with digital control circuits for reduced component count, and synchronous rectifiers for high power conversion efficiency. Of course, the broad scope of the present invention is not limited to a power module, power converter or the like, and may be applicable to other electronic devices.

A conductive substrate (e.g., conductive leadframe or leadframe) **110** is patterned and etched to form an electrically conductive interconnect layer for the lower portion of a winding for the inductor as well as the electrical interconnections among surface-mount components, the integrated circuit, and the inductor. A typical thickness of the leadframe **110** is about eight mils. While the leadframe **110** is often constructed of copper, alternative electrically conductive materials can be used therefor. The leadframe **110** provides external connections for the power module, as well as a support base for a magnetic material for the inductor. The external connections are formed as fingers of the leadframe **110**, referenced as leadframe fingers (two of which are designated **115**, **116**).

The leadframe **110** is generally constructed with an integral strip surrounding the electrically conductive pattern to provide mechanical support during the manufacturing steps, which strip is discarded later in the manufacturing process. The surrounding strip is generally sheared off after the electronic device has been constructed. The leadframe **110** is generally produced in an array of repeating of patterns (not shown), such as a 16×16 array, to form, for example, 256 substantially identical electronic devices. Forming an array of leadframes **110** is a process well known in the art to reduce the manufacturing cost of producing the electronic devices.

Solder paste is selectively applied to the leadframe **110** in a thin layer to areas (one of which is designated **125**) for screening processes, to provide electrical and mechanical attachment for surface-mount components. The surface-mount components such as capacitors (one of which is designated **120**) are placed with their conductive ends in the solder paste. The solder paste may be composed of lead-based as well as lead-free compositions. The array of leadframes **110** with the surface-mount components **120** is reflowed in an oven to mechanically and electrically attach the surface-mount components **120** to the leadframe **110**.

The steps as described above generally do not require execution in the highly controlled environment of a clean room. The following steps, however, are preferably performed in a clean room environment such as typically used for assembly of integrated circuits into a molded plastic package, as is generally well known in the art.

An adhesive (e.g., a die attach adhesive such as Abletherm 2600AT by Ablestik of Rancho Dominquez, Calif.) is dispensed onto the leadframe **110** to hold a magnetic core (e.g., a bar of magnetic material) **130** and an integrated circuit in the form of a semiconductor die **140**. The bar of magnetic material **130** and the semiconductor die **140** are positioned on the leadframe **110** over the die attach adhesive. Thus, a lower surface of the bar of magnetic material **130** faces, and is preferably adhered to, the leadframe **110**. The bar of magnetic material **130** is included to enhance the magnetic properties of the inductor and may be about 250 micrometers (μm) thick, four mils wide and 7.5 mils long. The adhesive is cured, typically in a controlled thermal process, to secure the bar of magnetic material **130** and the semiconductor die **140** to the leadframe **110**.

Solder paste is applied to areas (generally designated **160**) of the leadframe **110** wherein ends of conductive clips **150** are placed. Again, the solder paste may be composed of lead-based as well as lead-free compositions. The conductive clips **150** (e.g., about 8-12 mils thick) are placed on the leadframe **110** above the bars of magnetic material **130** with their ends in the solder paste. The conductive clips **150** are formed with their ends bent toward the leadframe **110** about ends of the bar of magnetic material **130** without mechanical interference.

Thus, an upper surface of the bar of magnetic material **130** faces the conductive clips **150**. An insulating gap, for example, about a five mil air gap, is thus preferably left between the upper surfaces of the bars of magnetic material **130** and the lower surfaces of the conductive clips **150**, which gap may be filled later by an encapsulant. The conductive clips **150** provide the portion of the electrically conductive inductor winding above each bar of magnetic material **130**. The leadframe **110** is heated in a reflow oven to mechanically and electrically bond the conductive clips **150** to the leadframe **110**.

Wire bonds preferably formed of gold wire such as a first wire bond **165** are attached to each semiconductor die **140** and to the leadframe **110** to electrically couple pads on the semiconductor die **140** to bonding areas of the leadframe **110** thereby providing electrical circuit connections therebetween. Wire bonds such as a second wire bond **166** may also be used to selectively electrically couple portions of the leadframe **110** to provide circuit interconnections that cannot be easily wired in a single planar layout, thus producing the topological layout equivalent for the leadframe **110** of a two-layer printed wiring board or substrate.

When the electronic devices are formed in an array as mentioned above, the array is placed in a mold, and an encapsulant such as a molding material, preferably epoxy, is deposited (e.g., injected) thereover as is well known in the art to provide environmental and mechanical protection as well as a thermally conductive covering to facilitate heat dissipation during operation. Other molding materials and processes as well as electronic devices constructed without an encapsulant are well within the broad scope of the present invention.

The individual electronic devices are singulated from the array thereof by a punching and shearing operation to produce an encapsulated power module including power conversion circuitry as illustrated with respect to FIG. **3**. The power module is mechanically and hermetically protected by the encapsulant **170** as illustrated. External electrical connections to a system employing the power module are made via terminals **180** which are created from exposed leadframe fingers (see FIG. **1**) protruding from sides and a lower surface of the power module after encapsulation. Typically, the terminals **180** are substantially coplanar with the sides and lower surface of the power module. The terminals **180** are formed by the shearing and molding operation on the leadframe **110** as is well known in the art.

Electrical connections to the system employing the power module are made by placing the power module on another circuit board or printed wiring board formed with interconnect pads that are covered with solder paste, generally by a screening operation, and heating the power module on the circuit board in a reflow oven. The reflow soldering operation is generally also adequate to provide mechanical attachment of the power module to another printed wiring board, but other attachment methods such as adhesive compound are well within the broad scope of the present invention.

Turning now to FIG. **4**, illustrated is a diagram of an embodiment of a power converter including power conversion circuitry constructed according to the principles of the present invention. The power converter includes a power train **410**, a controller **420** and a driver **430**, and provides power to a system such as a microprocessor. While in the illustrated embodiment, the power train **410** employs a buck converter topology, those skilled in the art should understand that other converter topologies such as a forward converter topology are well within the broad scope of the present invention.

The power train **410** preceives an input voltage V_{in} from a source of electrical power (represented by a battery) at an input thereof and provides a regulated output voltage V_{out} to power, for instance, a microprocessor at an output thereof. In keeping with the principles of a buck converter topology, the output voltage V_{out} is generally less than the input voltage V_{in} such that a switching operation of the power converter can regulate the output voltage V_{out}. A switch (e.g., a main switch Q_{mn}) is enabled to conduct for a primary interval (generally co-existent with a primary duty cycle "D" of the main switch Q_{mn}) and couples the input voltage V_{in} to an output filter inductor L_{out}. During the primary interval, an inductor current I_{Lout} flowing through the output filter inductor L_{out} increases as a current flows from the input to the output of the power train **410**. A component of the inductor current I_{Lout} is filtered by the output capacitor C_{out}.

During a complementary interval (generally co-existent with a complementary duty cycle "1-D" of the main switch Q_{mn}), the main switch Q_{mn} is transitioned to a non-conducting state and another switch (e.g., an auxiliary switch Q_{aux}) is enabled to conduct. The auxiliary switch Q_{aux} provides a path to maintain a continuity of the inductor current I_{Lout} flowing through the output filter inductor L_{out}. During the complementary interval, the inductor current I_{Lout} through the output filter inductor L_{out} decreases. In general, the duty cycle of the main and auxiliary switches Q_{mn}, Q_{aux} may be adjusted to maintain a regulation of the output voltage V_{out} of the power converter. Those skilled in the art should understand, however, that the conduction periods for the main and auxiliary switches Q_{mn}, Q_{aux} may be separated by a small time interval to avoid cross conduction therebetween and beneficially to reduce the switching losses associated with the power converter.

The controller **420** receives a desired characteristic such as a desired system voltage V_{system} from an internal or external source associated with the microprocessor, and the output voltage V_{out} of the power converter. The controller **420** is also coupled to the input voltage V_{in} of the power converter and a return lead of the source of electrical power (again, represented by a battery) to provide a ground connection therefor. A decoupling capacitor C_{dec} is coupled to the path from the input voltage V_{in} to the controller **420**. The decoupling capacitor C_{dec} is configured to absorb high frequency noise signals associated with the source of electrical power to protect the controller **420**.

In accordance with the aforementioned characteristics, the controller **420** provides a signal (e.g., a pulse width modulated signal S_{PWM}) to control a duty cycle and a frequency of the main and auxiliary switches Q_{mn}, Q_{aux} of the power train **410** to regulate the output voltage V_{out} thereof. The controller **420** may also provide a complement of the signal (e.g., a complementary pulse width modulated signal $S_{1\text{-}PWM}$) in accordance with the aforementioned characteristics. Any controller adapted to control at least one switch of the power converter is well within the broad scope of the present invention. As an example, a controller employing digital circuitry is disclosed in U.S. Pat. No. 7,038,438, entitled "Controller for a Power Converter and a Method of Controlling a Switch Thereof," to Dwarakanath, et al. and U.S. Pat. No. 7,019,505, entitled "Digital Controller for a Power Converter Employing Selectable Phases Of A Clock Signal," to Dwarakanath, et al., which are incorporated herein by reference.

The power converter also includes the driver **430** configured to provide drive signals S_{DRV1}, S_{DRV2} to the main and auxiliary switches Q_{mn}, Q_{aux}, respectively, based on the signals S_{PWM}, $S_{1\text{-}PWM}$ provided by the controller **420**. There are a number of viable alternatives to implement a driver **430** that include techniques to provide sufficient signal delays to prevent crosscurrents when controlling multiple switches in the power converter. The driver **430** typically includes switching circuitry incorporating a plurality of driver switches that cooperate to provide the drive signals S_{DRV1}, S_{DRV2} to the main and auxiliary switches Q_{mn}, Q_{aux}. Of course, any driver **430** capable of providing the drive signals S_{DRV1}, S_{DRV2} to control a switch is well within the broad scope of the present invention. As an example, a driver is disclosed in U.S. Patent Application Publication No. 2005/0168203, entitled "Driver for a Power Converter and Method of Driving a Switch Thereof," to Dwarakanath, et al., which is incorporated herein by reference. Also, an embodiment of a semiconductor device that may embody portions of the power conversion circuitry is disclosed in U.S. Pat. No. 7,230,302, entitled "Laterally Diffused Metal Oxide Semiconductor Device and Method of Forming the Same," to Lotfi, et al., which is incorporated herein by reference, and an embodiment of an integrated circuit embodying power conversion circuitry, or portions thereof, is disclosed in U.S. Pat. No. 7,015,544, entitled "Integrated Circuit Employable with a Power Converter," to Lotfi, et al., which is incorporated by reference.

Thus, a magnetic device, a power module and a method of manufacture thereof with readily attainable and quantifiable advantages have been introduced. Those skilled in the art should understand that the previously described embodiments of the magnetic device and power module are submitted for illustrative purposes only. In addition, other embodiments capable of producing a magnetic device and a power module while addressing compact, efficient and high density power modules, while being manufacturable at high volume and with lower cost than is achieved with the prior art are well within the broad scope of the present invention. While the magnetic device has been described in the environment of a power converter, the magnetic device may also be incorporated into other electronic devices, systems or assemblies such as communication or computing devices or other power processing devices.

As mentioned above, the present invention provides a magnetic device including a magnetic core having a surface facing a conductive substrate and a conductive clip facing a surface of the magnetic core with ends of the conductive clip electrically coupled to the conductive substrate to cooperatively form a winding therewith about the magnetic core. As an example, the present invention provides an inductor compatible with ordinary manufacturing and packaging processes for power management integrated circuits. The inductor includes a magnetic core formed from a bar of magnetic material adhered to conductive substrate (e.g., a patterned, conductive leadframe) and at least one conductive clip is placed above the bar of magnetic material to complete the portion of the inductor winding above the leadframe. Preferably, the conductive clip is made of copper, but other electrically conductive materials are well within the broad scope of the present invention. The bar of magnetic material is adhered to the leadframe with a die attach adhesive, and the at least one conductive clip is soldered to the leadframe. The inductor is preferably encapsulated with plastic encapsulating compound including an epoxy.

In an exemplary embodiment, the bar of magnetic material includes a ceramic material such as a soft magnetic ferrite having manganese zinc or nickel zinc ferrite. In a further exemplary embodiment, the bar of magnetic material is formed with a metallic alloy such as an iron cobalt alloy deposited via an electroplating process on a semiconductor or insulating die such as a silicon die. The at least one conductive clip may be soldered to the leadframe in a reflow soldering process. Additionally, a gap may be formed between the at least one conductive clip and the bar of magnetic material. In accordance therewith, the gap is typically filled with plastic encapsulating compound. The integrated circuit is also adhered to the leadframe. Preferably, the integrated circuit is wire bonded (via, for instance, gold wires) to the leadframe to form electrical connections therebetween. Surface-mount components may also be soldered to the leadframe.

In accordance with another aspect of the present invention, a magnetic device, integrated circuit and surface-mount components are integrated to form an electronic device such as a power module or power management integrated circuit. In other aspects, the present invention provides methods of forming the magnetic device and power module that take advantage of current practices in the field of power management integrated circuits.

For a better understanding of power converters, see "Modem DC-to-DC Switchmode Power Converter Circuits," by Rudolph P. Sevems and Gordon Bloom, Van Nostrand Reinhold Company, New York, N.Y. (1985) and "Principles of Power Electronics," by J.G. Kassakian, M. F. Schlecht and G. C. Verghese, Addison-Wesley (1991). For a better understanding of magnetic devices, see "Soft Ferrites: Properties and Applications," by E. C. Snelling, published by Butterworth-Heinemann, Second Edition, 1989. The aforementioned references are incorporated herein by reference in their entirety.

Also, although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. For example, many of the processes discussed above can be implemented in different methodologies and replaced by other processes, or a combination thereof.

Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

What is claimed is:

1. A method of forming a magnetic device employable in a power module, comprising:

providing a conductive substrate employable in said power module;

placing a magnetic core proximate said conductive substrate with a lower surface adhered to an adhesive on said conductive substrate, said magnetic core having an overall end-to-end length and a continuous upper surface;

placing a planar surface of a conductive clip above said continuous upper surface of said magnetic core, said conductive clip continuously spanning said overall end-to-end length and said continuous upper surface of said magnetic core in a plane parallel to said conductive substrate; and

electrically coupling ends of said conductive clip to said conductive substrate to allow said conductive clip to form a portion of a winding about said magnetic core.

2. The method as recited in claim **1** wherein said conductive clip is about 8 to 12 mils in thickness.

3. The method as recited in claim **1** wherein said continuous upper surface of said magnetic core is substantially planar.

4. The method as recited in claim **1** wherein said magnetic core is formed from manganese zinc ferrite.

5. The method as recited in claim **1** wherein said conductive substrate is a leadframe.

6. The method as recited in claim **1** wherein said adhesive is a die attached adhesive.

7. The method as recited in claim **1** wherein said ends of said conductive clip are bent toward said conductive substrate about ends of said magnetic core.

8. The method as recited in claim **1** further comprising soldering said conductive clip to said conductive substrate.

9. The method as recited in claim **1** further comprising providing a gap between said conductive clip and said magnetic core.

10. The method as recited in claim **1** further comprising encapsulating said magnetic core, said conductive clip and said conductive substrate.

11. The method as recited in claim **1** wherein said continuous upper surface of said magnetic core is rectangular.

12. A method of forming a magnetic device employable in a power module, comprising:

providing a patterned, conductive leadframe employable in said power module;

adhering a magnetic core formed from a bar of magnetic material to an adhesive on said conductive leadframe, said magnetic core having an overall end-to-end length and a continuous upper surface;

placing a planar surface of at least one conductive clip above said continuous upper surface of said magnetic core, said at least one conductive clip continuously spanning said overall end-to-end length and said continuous upper surface of said magnetic core in a plane parallel to said conductive leadframe; and

soldering ends of said at least one conductive clip to said conductive leadframe to allow said conductive clip to form a portion of a winding about said magnetic core.

13. The method as recited in claim **12** wherein said bar of magnetic material is formed from manganese zinc ferrite.

14. The method as recited in claim **12** further comprising forming terminals for external electrical connections by creating leadframe fingers in said conductive leadframe.

15. The method as recited in claim **12** further comprising electrically coupling portions of said conductive leadframe with at least one wire bond.

16. The method as recited in claim **12** wherein said ends of said at least one conductive clip are bent toward said conductive leadframe about ends of said magnetic core.

17. The method as recited in claim **12** further comprising providing a gap between said magnetic core and said at least one conductive clip.

18. The method as recited in claim **12** further comprising providing a gap between said magnetic core and said at least one conductive clip and further comprising substantially filling said gap with an encapsulant.

19. The method as recited in claim **12** further comprising encapsulating said magnetic core, said at least one conductive clip and said conductive leadframe.

20. The method as recited in claim **12** further comprising encapsulating said magnetic core, said at least one conductive clip and said conductive leadframe with an epoxy encapsulant.

21. The method as recited in claim **12** wherein said magnetic device is an inductor.

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